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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

REPORT NO. 1169

GUNFIRE QUALIFICATION TEST OF
SELF-SEALING FUEL CELLS

FINAL Report

Copy No. _____

Task

Assignment TED No. NPG AF6608

Classification RESTRICTED
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Gunfire Qualification Test of Self-Sealing Fuel Cells

PART A

SYNOPSIS

1. This test was conducted to evaluate the self-sealing performance of the fuel cells when subjected to an internal pressure of 2 lbs./sq. in. and subjected to fragments from detonated 40mm HEP projectiles and .50 caliber AP and 20mm practice projectile impacts.

2. Upon examination of the first cell tested it was noted that none of the fragments from the detonated 40mm HEP projectile had penetrated the fuel cell. This was attributed largely to the thickness of the surrounding structure and backing material. One 20mm practice and three .50 caliber AP projectiles were fired into the fuel cell producing a total of eight wounds, five of which failed to seal in the allotted two minutes.

Fragments inflicted a total of six wounds in the second fuel cell tested, four of which sealed satisfactorily. One 20mm practice and three .50 caliber AP projectiles were fired into the fuel cell producing a total of seven wounds, three of which failed to seal in the allotted two minutes.

3. It is concluded that:

a. Of the six wounds inflicted in the fuel cell by fragments, four exhibited a satisfactory sealing performance.

b. Seven of the fifteen wounds inflicted in the fuel cells by .50 caliber AP and 20mm practice projectiles sealed satisfactorily in accordance with the requirements of paragraph 4.3.2.2.3.6 of Military Specification MIL-T-5578A.

Gunfire Qualification Test of Self-Sealing Fuel Cells

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Gunfire Qualification Test of Self-Sealing Fuel Cells

PART B

INTRODUCTION

1. AUTHORITY:

This test was conducted under Bureau of Aeronautics Project TED No. NPG AE6608, established and authorized by reference (a).

2. REFERENCES:

- a. BUAER Rest ltr Aer-Ae-664 Ser 55586 of 22 April 1953 with BUORD First Endorsement of 30 April 1953
- b. Military Specification MIL-T-5578A

3. BACKGROUND:

The Firestone Tire and Rubber Company submitted to the Naval Proving Ground for gunfire test two self-sealing fuel cells manufactured under the self-sealing tank development contract NOa(s)51-663.

4. OBJECT OF TEST:

As requested by reference (a) this test was conducted to evaluate the self-sealing performance of the fuel cells when subjected to an internal pressure of 2 lbs./sq. in. and subjected to fragments from detonated 40mm HEP projectiles and .50 caliber and 20mm practice projectile impacts.

5. PERIOD OF TEST:

- | | |
|---------------------------|---------------|
| a. Date of Project Letter | 22 April 1953 |
| b. Date Material Received | 5 June 1953 |
| c. Date Commenced Test | 15 June 1953 |
| d. Date Completed Test | 15 June 1953 |

6. REPRESENTATIVES PRESENT:

Mr. L. B. Copple
Mr. R. F. Wilson

Firestone Tire and Rubber Co.
Firestone Tire and Rubber Co.

Gunfire Qualification Test of Self-Sealing Fuel Cells
-----PART CDETAILS OF TEST

7. DESCRIPTION OF ITEMS UNDER TEST:

a. The subject test specimens are Firestone Tire and Rubber Company self-sealing fuel cells, construction No. 1156, and each has a usable capacity of 150 U. S. gallons. The fuel cells were enclosed in 75S-T aluminum panels and employed Swedlow backing material for additional support and protection.

b. The following pertinent data appear on the name plate of each cell:

Cell Self-Sealing Fuel Aircraft

Construction No. 1156

Serial No. 1169

Weight - 58 lbs.

Manufactured by Firestone Tire and Rubber Company,
California Division.

Submitted by Firestone Tire and Rubber Company 4-53 in
accordance with the requirements of BUAER Contract 51-663F
under authorization, BUAER ltr Aer-Ae-664-NOAS 51-663
Ser 52768 of 16 April 1953.

8. DESCRIPTION OF TEST EQUIPMENT:

The following equipment was used in conducting this test:

a. Four 40mm HEP (TNT) projectiles, M-2, assembled with tracer and Mk 27 nose fuze modified for static detonation.

b. .50 caliber accuracy gun

c. .50 caliber armor piercing ammunition

d. 20mm T-31 aircraft machine gun

e. 20mm practice ammunition

f. Compressor

g. Iso-octane fuel

Gunfire Qualification Test of Self-Sealing Fuel Cells

9. PROCEDURE:

Each of the two fuel cells was filled to within two inches of the top with iso-octane fuel and subjected to fragments from statically detonated 40mm HEP projectiles placed 24 inches from the outside of the structure. Both fuel cells were also subjected to .50 caliber AP and 20mm projectile impacts. An internal pressure of 2 lb./sq. in. was applied to the fuel cells throughout the gunfire test. The ambient temperature during the test was +73°F.

10. RESULTS AND DISCUSSION:

a. Cell No. 1:

(1) 40mm Detonation

Upon examination of the fuel cell at the conclusion of the gunfire test it was noted that none of the fragments from the detonated 40mm HEP projectile had penetrated the cell. The failure of the fragments to penetrate the cell was attributed largely to the thickness of the structure and backing material.

(2) Gunfire Test:

One 20mm practice and three .50 caliber armor piercing projectiles were fired into the fuel cell, producing a total of nine wounds. One of these could not be observed, because the projectile did not penetrate the structure completely, and therefore it was not evaluated. The entrance wounds were designated by number in order of impact; the exit wounds by the numbers followed by an X. Of the eight wounds evaluated, five were leaking at the end of the allotted two minutes as follows: 1 - (20mm) leaking slightly; 1X (20mm) leaking heavily; 2X and 3X (.50 Cal.) leaking heavily (the projectiles were stuck in the wounds preventing the sealant from acting) and 4X (.50 Cal.) leaking moderately.

(3) The entrance and exit wounds in the fuel cell are shown in Figures 2 and 3 of Appendix (A). The damage inflicted to the structure by the detonated 40mm fragments is shown in Figure 4, and the damage inflicted by the 20mm and .50 caliber projectile impacts in Figures 5 and 6.

(4) Tabulated results of the test are contained in Table I of Appendix (B).

Gunfire Qualification Test of Self-Sealing Fuel Cells
-----b. Cell No. 2:

(1) 40mm Detonation

Three 40mm HEP projectiles were detonated for the fragmentation test. Fragments from the first projectile failed to penetrate the cell. A total of six wounds were inflicted in the fuel cell by fragments from the second and third projectiles. Four of the wounds sealed satisfactorily, and two were seeping slightly at the end of the allotted two minutes.

(2) Gunfire Test

One 20mm practice projectile and three .50 caliber AP projectiles were fired into the fuel cell, producing a total of nine wounds. One of these could not be observed, because the projectile failed to penetrate the structure completely, and therefore it was not evaluated. Of the seven wounds evaluated three were leaking at the end of the allotted two minutes as follows: 1 - (20mm) leaking moderately; 1X (20mm) leaking heavily; 3X (.50 Cal.) seeping slightly.

(3) The entrance and exit wounds in the fuel cell are shown in Figures 7 and 8 of Appendix (A). The damage inflicted to the structures by the 40mm fragments, 20mm practice and .50 caliber AP projectile impacts are shown in Figures 9, 10, 11 and 12.

(4) Tabulated results of the test are contained in Table II of Appendix (B).

Gunfire Qualification Test of Self-Sealing Fuel Cells
-----PART DCONCLUSIONS

11. It is concluded that:

a. Of the six wounds inflicted in the fuel cell by fragments, four exhibited a satisfactory sealing performance.

b. Seven of the fifteen wounds inflicted in the fuel cells by .50 caliber AP and 20mm practice projectiles sealed satisfactorily in accordance with the requirements of reference (b).

PART EDISPOSITION OF MATERIAL

12. The material used in this test will be disposed of as directed by reference (a).

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NPG REPORT NO. 1169

Gunfire Qualification Test of Self-Sealing Fuel Cells

The tests upon which this report is based were conducted by:

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NPG REPORT NO. 1169

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

Final Report
on
Gunfire Qualification Test of
Self-Sealing Fuel Cells

Project No.: TED No. NPG AE6608
No. of Pages: 8

Date:

AUG 25 1953

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NP9-63600

15 June 1953

Gunfire Qualification Test of Firestone Tire & Rubber Company Self Sealing Fuel Cells.
View showing subject specimen mounted on gunfire test, with fragments from a detonated
40mm LP projectile and 50 caliber M163M practice projectile impacts.

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Figure 1

Appendix A

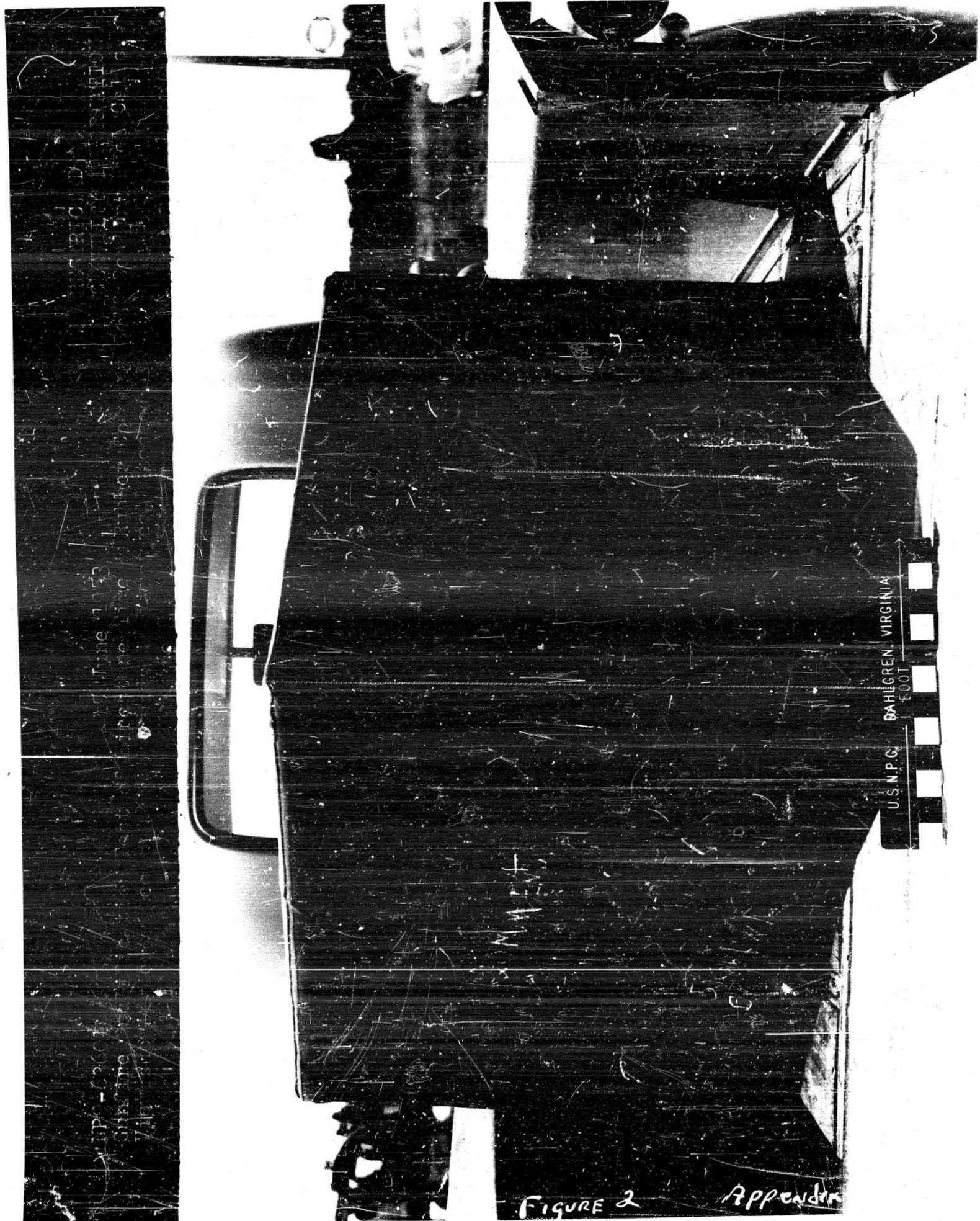


FIGURE 2

Appendix

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Rubber Company Self Sealing Fuel Cells.

15 June 1953

100-63602

100-63602

100-63602

100-63602

CELL SELF SEALING FUEL AIRCRAFT
CONST NO 1156

SERIAL NO 1168

WEIGHT 600 LBS

MFG'D BY FIRESTONE TAR CO

CALIF DIV

SUBMITTED BY FIRESTONE TAR CO 4-53
IN ACCORDANCE WITH THE REQUIREMENTS OF
BOMBER CONTRACT 51-663F UNDER
AUTHORIZATION, BOMBER LTR AER-AE-663
MAY 51-663 SER 52768 OF 14 APR 1953

DAHLGREN, VIRGINIA

U.S.N.P.C.

Figure 3

Appendix

NP9-63603

Qualification test of Firestone Tire & Rubber Company self-sealing fuel cells. View showing structure in detector station detector 40m.

15 June 1953

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1



Appendix A

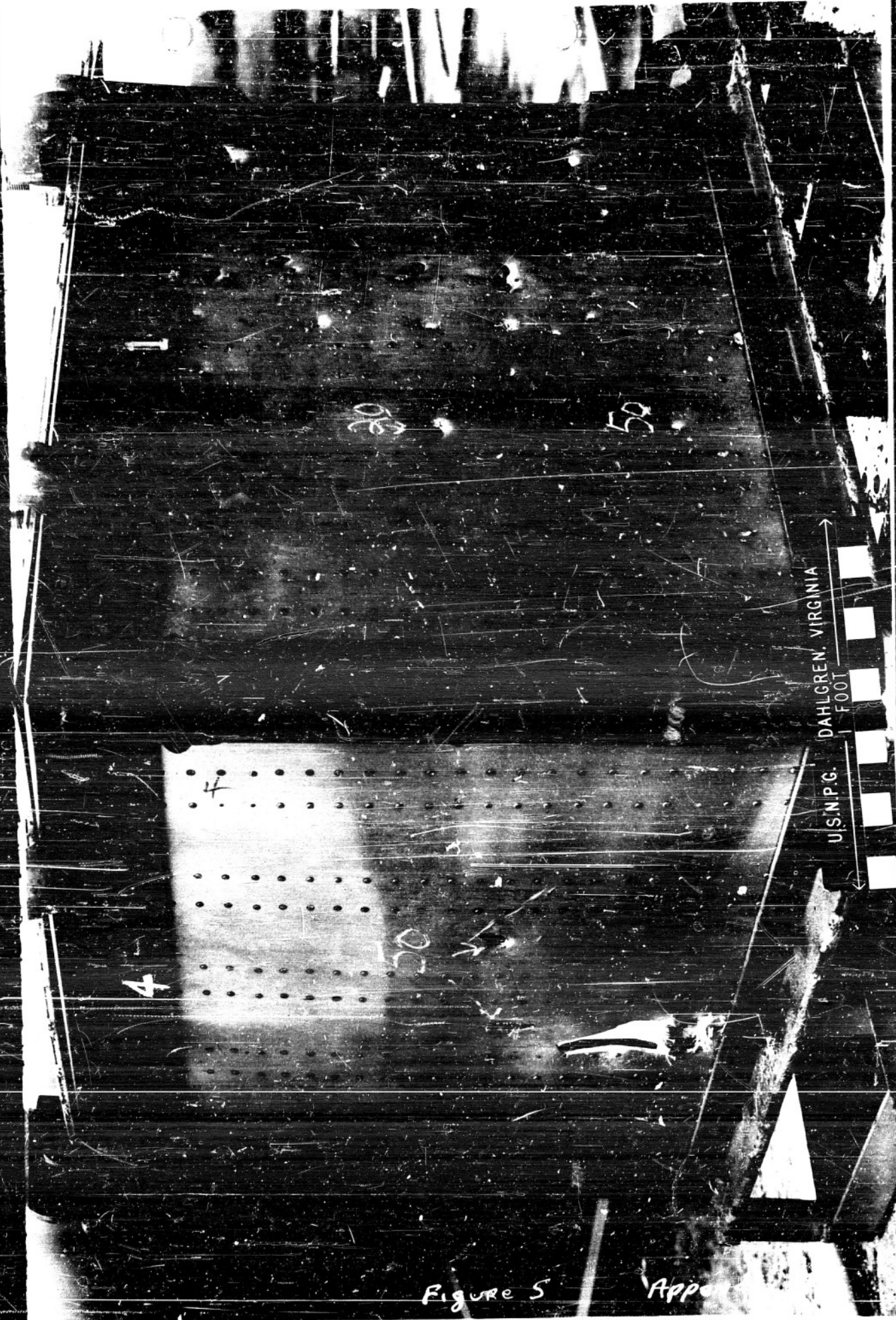
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15 June 1953

WFO-63604

Gunfire Simulation Test of Firestone Tire Rubber Company Self-Sealing Fuel Cells.
View showing damage to test structure inflicted by 1.5 caliber AP and 20mm practice
projectile.

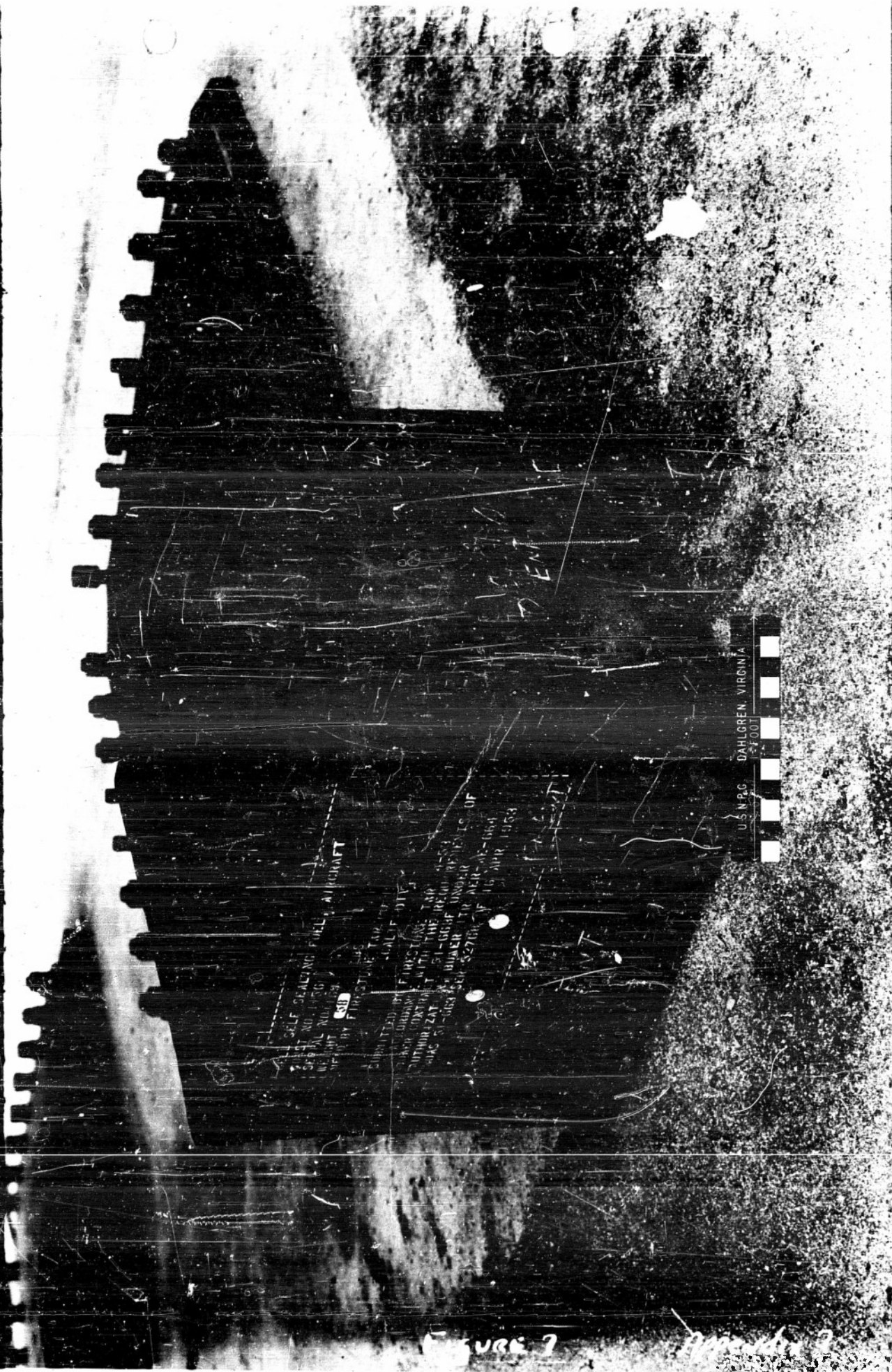


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15 June 1953

NP9-63606
Gunfire Qualification Test of Firestone Tire & Rubber Company Self Sealing Fuel Cells.
View showing wounds in second fuel cell tested.

Figure 7



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15 June 1953

IP9-63607
Gunfire qualification test of Firestone Tire & Rubber Company Self Sealing Fuel Cells.
View showing rounds in second fuel cell tested.



FIGURE 8

NP9-63608

15 June 1953

Gunfire Qualification Test of Firestone Tire & Rubber Company Self Sealing Fuel Cells.
View showing damage to structure inflicted by fragments from a detonated 40mm HEF projectile.

Figure 9

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MP9-63609

15 June 1953

Gunfire Qualification Test of Wirestone Tire & Rubber Company Self Sealing Fuel Cells.
View showing damage to structure inflicted by fragments from two detonated 40mm HRP
projectiles.

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Appendix

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Figure 11

Appendix A

IPD-13011

gunfire

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FOOT

Appendix A

Gunfire Qualification Test of Self-Sealing Fuel Cells
-----TABULATED RESULTS OF GUNFIRE TEST

Preliminary Notes:

1. In the following table the following abbreviations are used:

SRH	Small round hole
LH	Leaking heavily
LM	Leaking moderately
LS	Leaking slightly
SS	Seeping slightly

Gunfire Qualification Test of Self-Sealing Fuel Cells

TABLE I

TABULATED RESULTS OF GUNFIRE TEST

Weather - Clear		Humidity - 57%		Date: 15 June 1953	
Temperature - +72°F		Wind - NW-3K			
Specimen	Firestone Tire and Rubber Company Self-Sealing Fuel Cells	1	2	3	4
Entrance Round No.	Detonation	L.M.	Damp	S.S.	Damp
Leakage, Impact	-	L.S.	-	Damp	-
(2 Min.)	-	L.S.	-	-	-
(5 Min.)	-	5/8"	1"	1-1/2"	SRH
Size of Wound	-	5"	12"	12-1/2"	18-1/2"
Head of Fuel	-	-	-	-	-
Location of Impact	-	0°	0°	0°	45°
Oblliquity Angle	0°				
Type Fuel	Iso-octane	Iso-octane	Iso-octane	Iso-octane	Iso-octane
Type Ammunition	40mm HEP Proj.	20mm Practice	.50 Cal. AP	.50 Cal. AP	.50 Cal. AP
Type of Impact	Fragments	Non-tumbled	1/2 Tumble	3/4 Tumble	Non-tumbled
Remarks	Fragments did not penetrate cell.	Wound sealed to damp after pressure was released.			
Exit Data-Round		1X	2X	3X	4X
Size Hole (In.)		2" - 5/8"	7/8"	1-1/2"	2"
Head of Fuel		10" - 7"	8"	17"	19-1/2"
Leakage, Impact		L.H. - Unobserved	L.H.	L.H.	L.M.
(2 Min.)		L.H. -	L.H.	L.H.	L.M.
(5 Min.)		L.H. -	L.H.	L.H.	L.M.
Remarks		Wound continued to seep slightly after pressure was released.	Projectile stuck in wound.	Projectile stuck in wound.	Wound sealed to damp upon release of pressure.

Gunfire Qualification Test of Self-Sealing Fuel Cells

TABLE II

TABULATED RESULTS OF GUNFIRE TEST

Weather - Clear		Humidity - 57%		Date: 15 June 1953	
Temperature - +74°F		Wind - WSW-4K			
Specimen	Firestone Tire and Rubber Company Self-Sealing Fuel Cells				
Entrance Round No.	Detonation				
Leakage, Impact	Detonation	S.S.	Damp	Damp	Detonation
(2 Min.)	-	S.S.	-	-	L.M.
(5 Min.)	-	S.S.	-	-	L.M.
	-	S.S.	-	-	L.M.
Size of Wound	1/2" 3/4"	1/2"	1/4"	1/2"	5/8"
Head of Fuel	4-1/2" 17-1/2"	17"	14"	5"	9-1/2"
Location of Impact	-	-	-	-	-
Obliquity Angle	0°	0°	0°	0°	0°
Type Fuel	Iso-octane			Iso-octane	
Type Ammunition	40mm HEP Proj.			20mm Practicoe	
Type of Impact	Fragments			Non-tumbled	
Remarks	Fragments did not penetrate cell.			Wound sealed to damp after pressure was released.	

Exit Data-Round
Size Hole (In.)
Head of Fuel
Leakage, Impact
(2 Min.)
(5 Min.)
Remarks

IX
1-5/8"
14-1/2"
L.H.
L.H.
L.H.

Wound continued to leak moderately after pressure was released.

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Gunfire Qualification Test of Self-Sealing Fuel Cells

TABLE II (Continued)

Specimen Entrance Round No.	Tire and Rubber Company	Self-Sealing Fuel Cells	Date: 15 June 1953
Leakage, Impact (2 Min.) (5 Min.)	2 S.S. Damp	3 S.S. S.S. S.S. 1"	4 S.S. Damp - SRH
Size of Wound	7/8"	12-1/2"	12-1/2"
Head of Fuel	12-1/2"	-	-
Location of Impact	-	0°	45°
Obliquity Angle	0°	-	-
Type Fuel	Iso-octane	Iso-octane	Iso-octane
Type Ammunition	.50 Cal. AP	.50 Cal. AP	.50 Cal. AP
Type of Impact	1/2 Tumble	1/2 Tumble	Non-tumbled
Remarks			
Exit Data-Round	2X	3X	4X
Size Hole (In.)	1"	1-1/4"	1/2" - 1/2"
Head of Fuel	18"	9-1/2"	15-1/2" - 15-1/2"
Leakage, Impact (2 Min.) (5 Min.)	Unobserved - -	S.S. Damp -	S.S. Damp Damp -
Remarks	Proj. did not penetrate the structure.		Jacket separated from proj. in-flicting one additional wound.